



Delay-Tolerant Networks for Space Combat Cloud

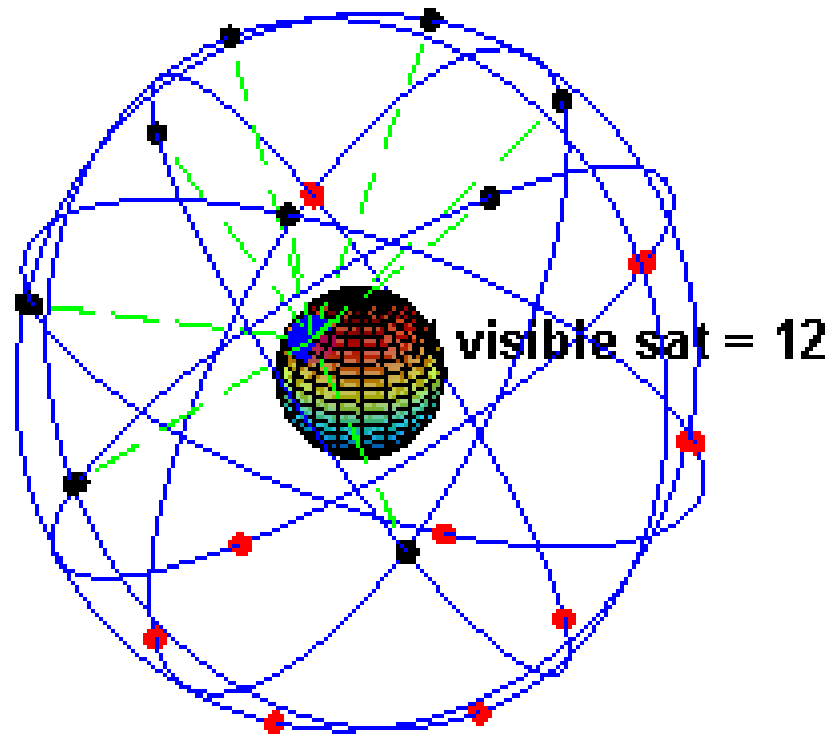
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13 December 2018

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. (c) 2018 California Institute of Technology. Government sponsorship acknowledged.



Stage 1 Topology





Stage 1 Summary

- Stage 1: single-domain private network with TBD #N max clients.
 - Intra-constellation links
 - 255 satellites (8 links/sat)
 - Links RF or optical
 - 1 network/security domain (option to add commercial internet tunnel)
 - Timing precision consistent with GPS needs ($\sim 1\text{nS}$ on platform, $\sim 5\text{nS}$ in six hop linkage)
 - Modest bandwidth performance ($< 1\text{gpbs}$) at long distance GEO; 5-20 Mbps at up to 2xGEO distances
 - Resiliency through mesh network



How does DTN help?

Benefits of DTN in Stage-1 space combat cloud:

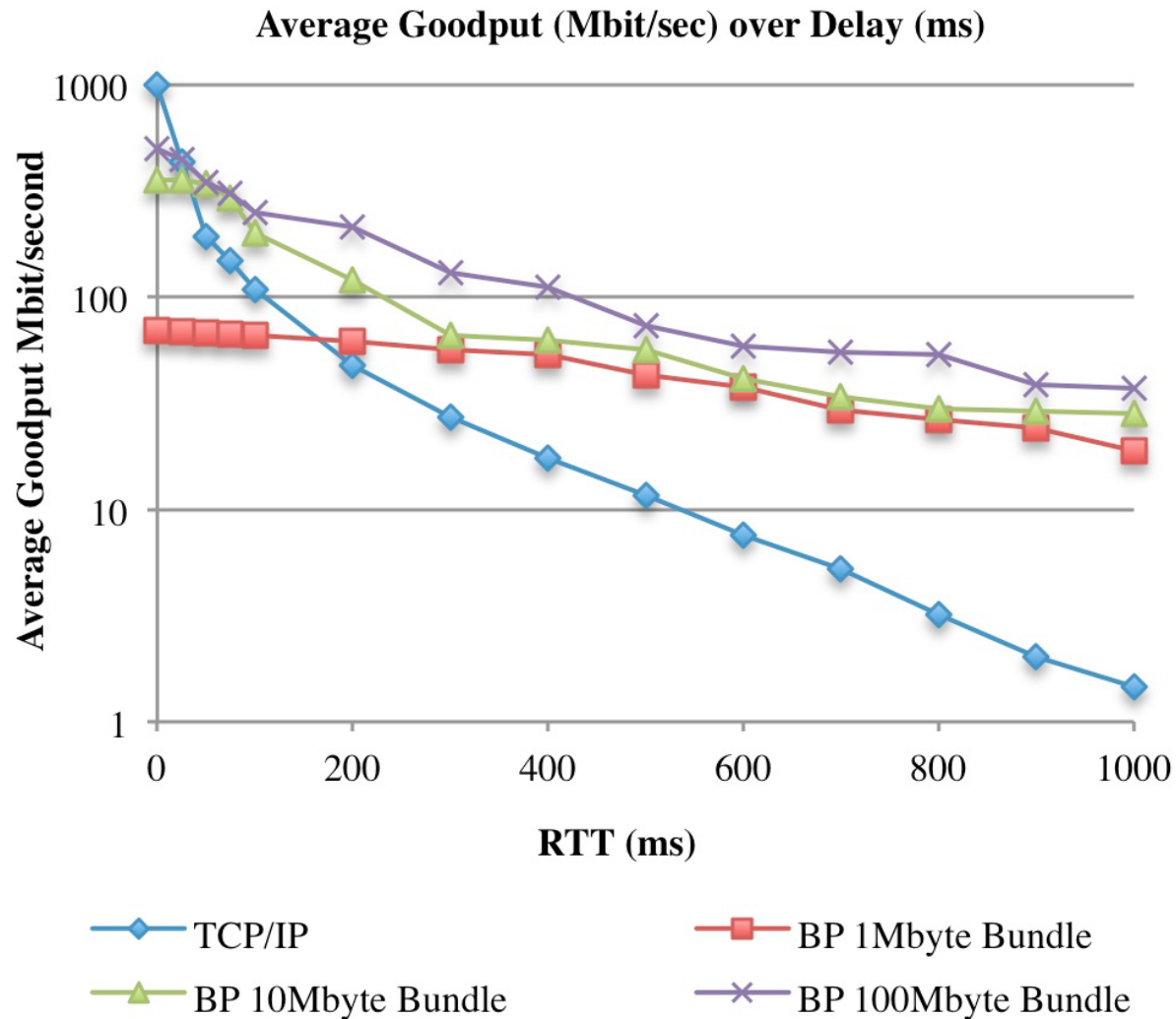
1. Performance
2. Routing
3. Security
4. Economy
5. Streaming
6. Multicast



Performance

- Satellite traffic will be subject to transient outages on handover from one ground station to the next, or from one GEO satellite to the next.
- If GEOs are used as the backbone, round-trip latency is on the order of 500 ms.
- Retransmission of lost data in a DTN occurs between topologically adjacent nodes inside the network, not end-to-end between the source and destination. TCP/IP is used at the DTN “convergence layer”, between BP nodes, not end-to-end.
- So data lost (during a handover or elsewhere) are quickly recovered inside the network, improving throughput.

Advantage





Routing

- The satellites in the combat cloud will be in motion, so all communication opportunities will be transient.
- But those opportunities will be predictable, because the orbital movement will not be random.
- Unlike Internet routing protocols, the “contact graph routing” algorithms developed for DTN were designed for exactly this sort of topology.
 - Routes are computed locally from a known contact plan.
 - Contacts are not discovered randomly; they are scheduled.
 - Although connectivity changes constantly, the contact plan remains static and routes do not change.



Security

- The DTN bundle security protocol provides authentication, integrity protection, and confidentiality end-to-end at the “bundle layer” of the protocol stack.
- Multiple cipher suites can be supported within the same network, and even within a single bundle.
- Individual blocks of a bundle can be protected in different ways, potentially using different cipher suites.
- Bundle-in-bundle encapsulation provides defense against traffic analysis.



Economy

- The DTN “delay-tolerant payload conditioning” application-layer protocol was specifically designed to support situational awareness applications.
- Small situational telemetry records are aggregated into larger application data units that are issued in DTN bundles.
- While aggregation is in progress, each new telemetry record is passed to a mission-defined “callback” function that performs application data elision as needed: redundant or superseded records may be removed from the aggregation as newer information arrives.
- The bundles that are issued contain only information of value, and protocol overhead is kept to a minimum.



Streaming

- End-to-end latency in streaming of audio, video, and telemetry introduces conflict between the requirement for timeliness and the requirement for accuracy and completeness.
- The DTN bundle streaming service resolves this conflict by managing two classes of output at the receiving node:
 - Data that were received in-order, end-to-end, are presented immediately for real-time display, possibly with some gaps.
 - Any data loss results in retransmission; the retransmitted data are necessarily forwarded out of order.
 - Data received out of order are merged with the in-order data in a time-ordered database, from which a gap-free stream can be reviewed in a separate replay display.



Multicast

- Because retransmission of lost data in DTN is performed between adjacent nodes in the network topology, rather than end-to-end, bundle multicast can be comprehensively reliable.
- Bundle multicast is multi-source and delay-tolerant.
- Streaming data, e.g., can be securely and reliably multicast over any combination of satellite and ground links.



Questions?

